PATENT SPECIFICATION

(11) 1449329

1449329

(21) Application No. 7748/74 (22) Filed 20 Feb. 1974
(31) Convention Application No. 22537/73 (32) Filed 24 Feb. 1973 in
(33) Japan (JA)
(44) Complete Specification published 15 Sept. 1976
(51) INT CL² F16F 15/26
(52) Index at acceptance
F1M 18

(19)

(54) DEVICE FOR REMOVING OR REDUCING UNBALANCED INERTIA FORCE OF A RECIPROCATING INTERNAL COMBUSTION ENGINE

(71) We, NISSAN MOTOR COMPANY, LIMITED, a corporation organized under the laws of Japan, of No. 2, Takara-machi, Kanagawa-ku, Yokohama City, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a reciprocating internal combustion engine, and more particularly to a device for removing or reducing unbalanced inertia force of the internal combustion engine.

Generally, since the reciprocating internal combustion engine has moving parts and rotary parts such as pistons and connecting rods, unbalanced inertia forces of certain degrees are created by the influence of the number and arrangement of cylinders or disposition of crank pin. Thus these parts become sources of vibration and noise of the internal combustion engine. As the engine speed is increased, this tendency becomes remarkable. Therefore, reciprocating internal combustion engine engineers are now making great efforts to remove these unbalanced inertia forces.

According to the present invention, there is provided a balancing device for removing or reducing unbalanced inertia forces of a reciprocating internal combustion engine having a crank-shaft, the device consisting of two sets of balancing assemblies provided at the front and rear ends of said crank-shaft, respectively, each of said assembly comprising a cam member coaxially mounted on said crank-shaft, said cam member forming therein a cam groove around and spaced from said crank-shaft, a balancing mass member arranged to move reciprocatingly along an axis perpendicular to the axis of said crank-shaft, and a cam follower connected to said mass member such that said mass member is reciprocatingly driven by the rotational movement of said cam member, the mass of said balancing member and the profile of said cam groove being determined such that the reciprocating movement of said balancing mass member provides an inertia force substantially equal in magnitude but opposite in direction to half the unbalanced inertia force of the engine, the balancing mass members of said two assemblies being arranged to reciprocate in the same direction.

In the accompanying drawings:—

Fig. 1 is an explanatory view of the disposition of the crank pin of the internal combustion engine;

Fig. 2 is a sectional view of one embodiment of the device for removing unbalanced intertia forces of the reciprocating internal combustion engine according to the present invention;

Fig. 3 is a sectional view of the device taken along the line III—III in Fig. 2; and

Fig. 4 is an explanatory view of the profile of the cam groove of the rotatable member of the invention.

The device for removing the unbalanced inertia forces of the internal combustion engine will now be described with reference to a straight-type four-cylinder reciprocating internal combustion engine as an example. Fig. 1 shows the arrangement of the crank pins of a straight-type four-cylinder internal combustion engine now most widely used.

The first and fourth crank pins 1 and 4 are disposed so that they differ in phase angle by 180° from the second and third crank pins 2 and 3 in a four-cylinder internal combustion engine. It is well known that unbalanced inertia force in y direction (U_y) can be shown by the following formula when the engine speed is N in the aforementioned arrangement of the crank pins of the internal combustion engine:

$$U_y = 4Fq2 \cos 2\theta + 4Fq4 \cos 4\theta + 4Fq6 \cos 6\theta + 4Fq8 \cos 8\theta + \qquad (1)$$

where

$$F=\frac{WR}{g}\,.\,r\,.\,W^2$$

$$q2=\rho,\ =\frac{r}{l}$$

$$q4=\frac{1}{4}\rho^3$$

$$q6=\frac{9}{128}\rho^5$$

$$q8=\frac{5}{256}\rho^7$$

WR: weight of the reciprocating parts of the engine

r: $\frac{1}{2}\times$stroke

l: distance between the large and small ends of connecting rod

W: Angular velocity of crank-shaft

$$\left(\frac{2\pi N}{60}=W\right)$$

N: Engine speed

θ: rotary angle of crank-shaft

In the above formula, the value of the first term is greatest, and the values of the subsequent terms (second, third, etc.) are small and even negligible. Therefore, a device for removing the unbalanced inertia force represented by the first term will now be described as an example.

From the above equation, the unbalanced inertia force represented by the first term is 4Fq2 cos 2θ. Therefore, in order to remove this, it must add a force represented by the following formula:

$$\vec{F}_2=-4Fq2\cos 2\theta$$

and, in order to prevent creation of any turning moment, it is desired to add the force of half of $\vec{F}_2$ to both ends of the crank shaft. Therefore,

$$\vec{F}_2\ \text{Front}=\vec{F}_2\ \text{Rear}=-2Fq2\cos 2\theta \qquad (2)$$

$$\vec{F}_2\ \text{Front}=\vec{F}_2\ \text{Rear}=-2\frac{WR}{g}\,.\,\frac{r^2}{l}\,.\,W^2\,.\cos 2\theta \qquad (3)$$

The right side member of the formula (3) is represented by (mass)$\times$(acceleration), but if it is converted into the form of (mass)$\times$ displacement), it will be:

$$\frac{WRr^2}{2gl}\,.\cos 2\theta \qquad (4)$$

As the coefficient of cos 2θ of the formula (4) represents the amplitude, the displacement *a* of the reciprocable member for producing the force F_2 Front or F_2 Rear is determined by the following formula (5) if the mass of the reciprocable member is represented by m:

$$a\,.\,m=\frac{WRr^2}{2gl} \qquad (5)$$

One embodiment of the device of the present invention exemplified in consideration of the relationship obtained by the above formula (5) will now be described with reference to Figs. 2 and 3.

Fig. 2 shows sectional view of the essential part of the device of the present invention, with respect to one of two identical assemblies provided at the front and rear ends of a crankshaft, and numeral 1 indicates a crank-shaft rotatably provided through bearings 3 to the cylinder block 2. At the shaft 1a of the end of the crank-shaft 1 are provided integrally with the crank-shaft, a spacer 4, a cam member 5 and pulley 6 of the crank-shaft. The rotatable member 5 is divided into two parts by the plane perpendicular to the axial direction thereof, and cam groove 7 or slot having proper profile is formed approximately at the center thereof. On the other hand, at the side surface of the cylinder block 2 is secured a support 9 having a bore 8*a* by bolts 10. A balancing mass member 8 movable in the bore 8*a* in the direction which creates unbalanced inertia force. At one end of the member 8 having mass m inserted into the bore 8*a* of the support 9 is formed a T-shaped follower 12 engaged through a bushing 11 with the cam groove 7. Therefore, the balancing mass member 8 can be moved following the cam groove 7 of the cam member 5 when the crank shaft 1 is rotated.

As shown in Fig. 4, the cam groove 7 hav-

ing proper profile formed at the cam member 5 is so determined that when the rotary angle of the crank shaft 1 is at 0° and 180° (corresponding to y axis positions in Fig. 1), the balancing mass member 8 is positioned at the lowermost point, while when the rotary angle of the crank shaft 1 is at 90° and 270°, the balancing mass member is at the uppermost position, that is, the member 8 completes one cycle every time the rotary angle of the crank shaft 1 reaches 180°. The displacement *a* of the member 8 at this time is easily determined by applying the mass *m* of the member 8 properly determined according to the formula (5) since the right side terms of the formula (5) are already known from the elements of the engine.

Numeral 13 indicates a front cover, 14 an oil pan, 15 a seal for preventing oil leakage in the crank case, 16 a passage for supplying lubricating oil to the sliding surface of the balancing mass member 8.

The previous embodiment shows the example of the device for removing the unbalanced inertia force of the first term of the formula (1), but the present invention is not limited only to this. The same manner as above may be applied for removing the unbalanced inertia force of the second, third or fourth term of the formula (1). For example, the displacement a of the balancing mass member can be expressed as

$$\left(\frac{1}{4}\,\frac{r^3}{l^3}\right)\frac{WRr^2}{2glm}$$

for the second term and

$$\left(\frac{9}{128}\,\frac{r^5}{l^5}\right)\frac{WRr^2}{2glm}$$

for the third term. In this case, the cam groove profile is modified to cause the displacement *a* to satisfy also these two terms in addition to the fundamental relationship according to equation (5).

It should be understood from the foregoing description that since the device for removing unbalanced inertia force according to the present invention comprises the cam member rotating integrally with the crankshaft and having properly profiled cam groove formed thereon, and the balancing mass member for removing unbalanced inertia force by following the cam groove, unbalanced inertia force created in the internal combustion engine can be removed and accordingly the vibration and noise of the internal combustion engine can be remarkably reduced.

It should also be understood that the device of the present invention thus constructed is simple in construction, easy to manufacture, and low in cost.

WHAT WE CLAIM IS:—

1. A balancing device for removing or reducing unbalanced inertia forces of a reciprocating internal combustion engine having a crank-shaft, the device consisting of two sets of balancing assemblies provided at the front and rear ends of said crank-shaft, respectively, each of said assembly comprising a cam member coaxially mounted on said crank-shaft, said cam member forming therein a cam groove around and spaced from said crank-shaft, a balancing mass member arranged to move reciprocatingly along an axis perpendicular to the axis of said crankshaft, and a cam follower connected to said mass member such that said mass member is reciprocatingly driven by the rotational movement of said cam member, the mass of said balancing member and the profile of said cam groove being determined such that the reciprocating movement of said balancing mass member provides an inertia force substantially equal in magnitude but opposite in direction to half the unbalanced inertia force of the engine, the balancing mass members of said two assemblies being arranged to reciprocate in the same direction.

2. A device as claimed in claim 1, wherein said cam member is divided perpendicular to the axis thereof, and the cam groove thereof is engaged by a T-shaped cam follower.

3. A device as claimed in claim 1, wherein the cam groove of said cam member is so determined that when the rotary angle of the crank-shaft is at 0° and 180°, the balancing mass member is positioned at the lowermost point, while when the rotary angle of the crank-shaft is at 90° and 270°, the balancing mass member is positioned at the uppermost point.

4. A device as claimed in Claim 1, wherein the profile of the cam groove of said cam member is so determined that the displacement a of said cam member is represented by an equation

$$a=\frac{WRr^2}{2glm},$$

where

WR=Weight of the reciprocating parts of the engine

$r=\frac{1}{2}\times$ Stroke

l=Distance between the large and small ends of the connecting rod

m=Mass of the balancing member.

5. A device as claimed in Claim 1, wherein the profile of the cam groove of said cam member is determined by modifying the profiles which are determined using the equations

$$a=\frac{WRr^2}{2glm},$$

$$a=\frac{WRr^2}{2glm}\left(\frac{1}{4}-\frac{r^3}{l^2}\right),$$

$$a=\frac{WRr^2}{2glm}\left(\frac{9}{128}-\frac{r^5}{5}\right),$$

etc., respectively.

6. A balancing device constructed and arranged substantially as described herein with reference to the accompanying drawings.

MARKS & CLERK,
Chartered Patent Agents,
57 & 58 Lincoln's Inn Fields,
London, WC2A 3LS,
Agents for the applicant(s).

Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1976.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

FIG. 1

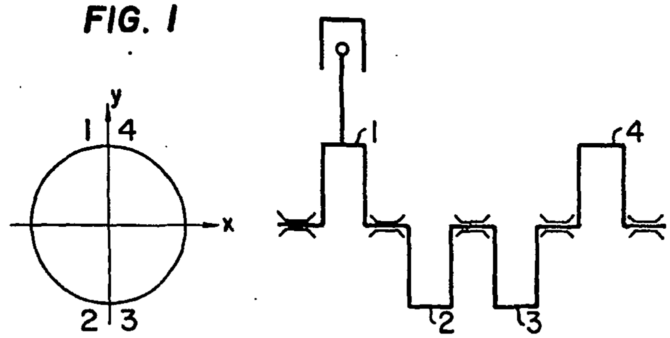


FIG. 2

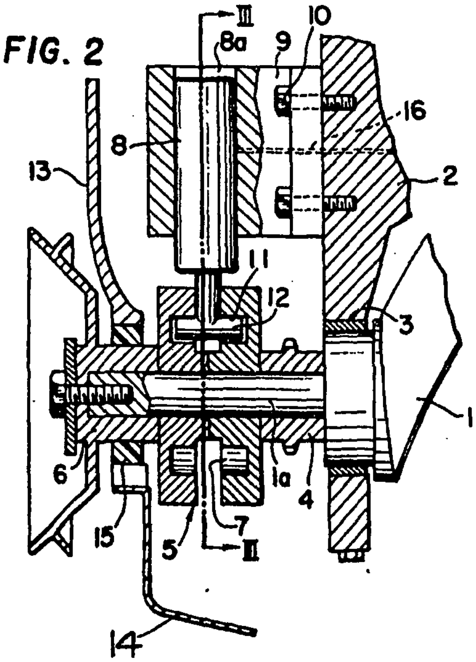


FIG. 3

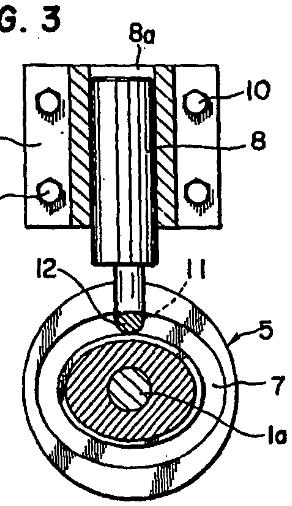
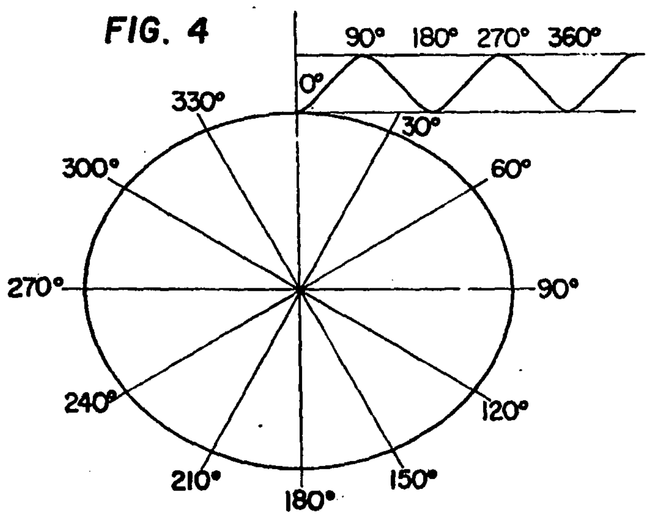

8a
10
9
8
10
12
11
5
7
1a

FIG. 4


90°
180°
270°
360°
0°
330°
30°
300°
60°
270°
90°
240°
120°
210°
180°
150°